

# R-Matrix analysis of $^{149}\text{Sm}$ using DICER and DANCE data

Th. Stamatopoulos<sup>1</sup>, P. Koehler<sup>1</sup>, A. Couture<sup>1</sup>, G. Rusev<sup>2</sup>, B. DiGiovine<sup>3</sup>

1. Physics Division, Los Alamos National Laboratory, 87545, NM, USA
2. Chemistry Division, Los Alamos National Laboratory, 87545, NM, USA
3. Weapons Stockpile Modernization Division, Los Alamos National Laboratory, 87545, NM, USA

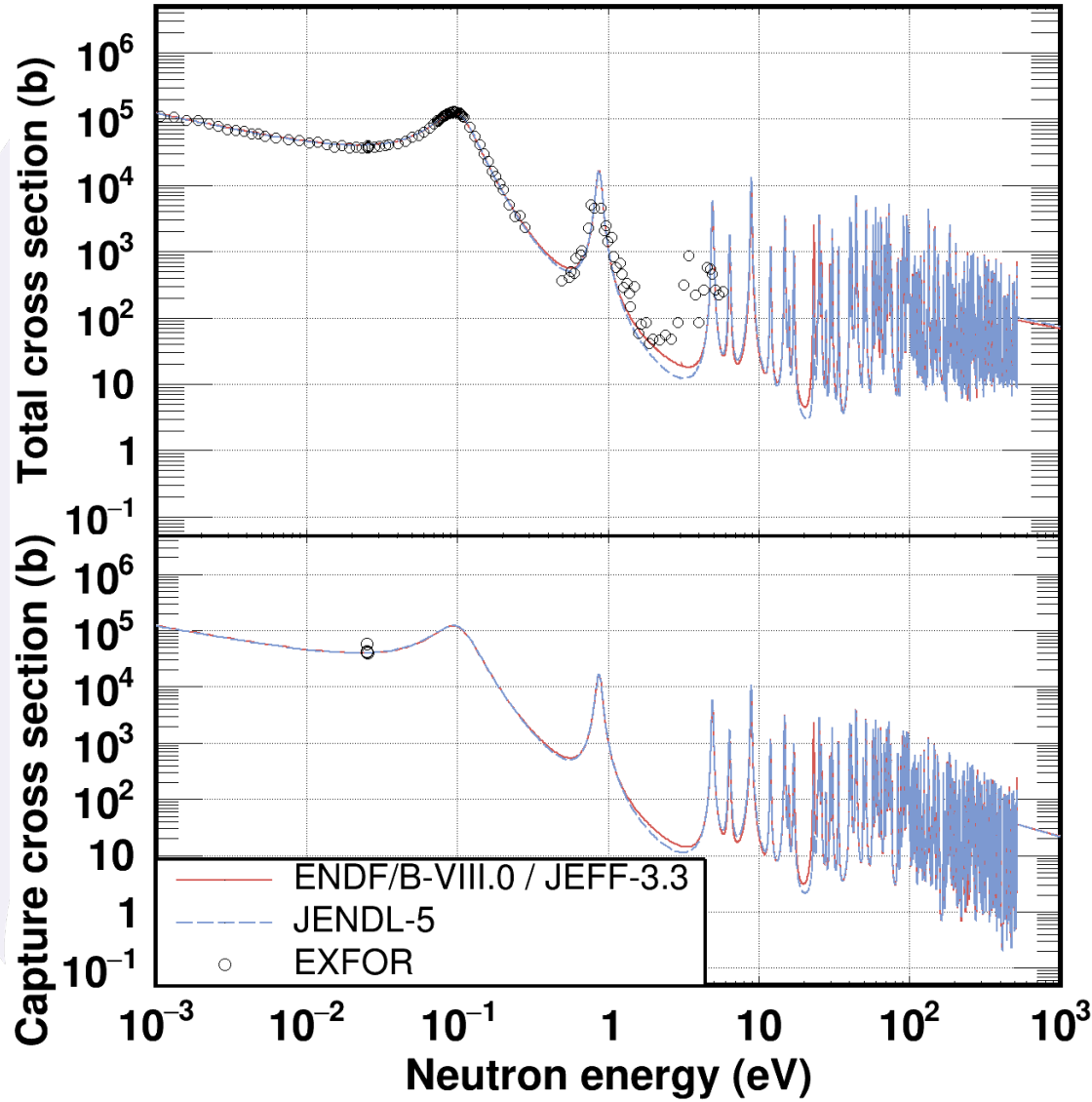
LA-UR-24-21273

# Introduction: Motivation

- According to a report by L. Leal (ORNL/TM-2005/065)

*$^{149}\text{Sm}$  capture rate underestimates measured capture rates for PWR experiments by 4.8%*

- Only a few data sets in EXFOR
- Resonance parameters do exist but better uncertainties and covariances are needed

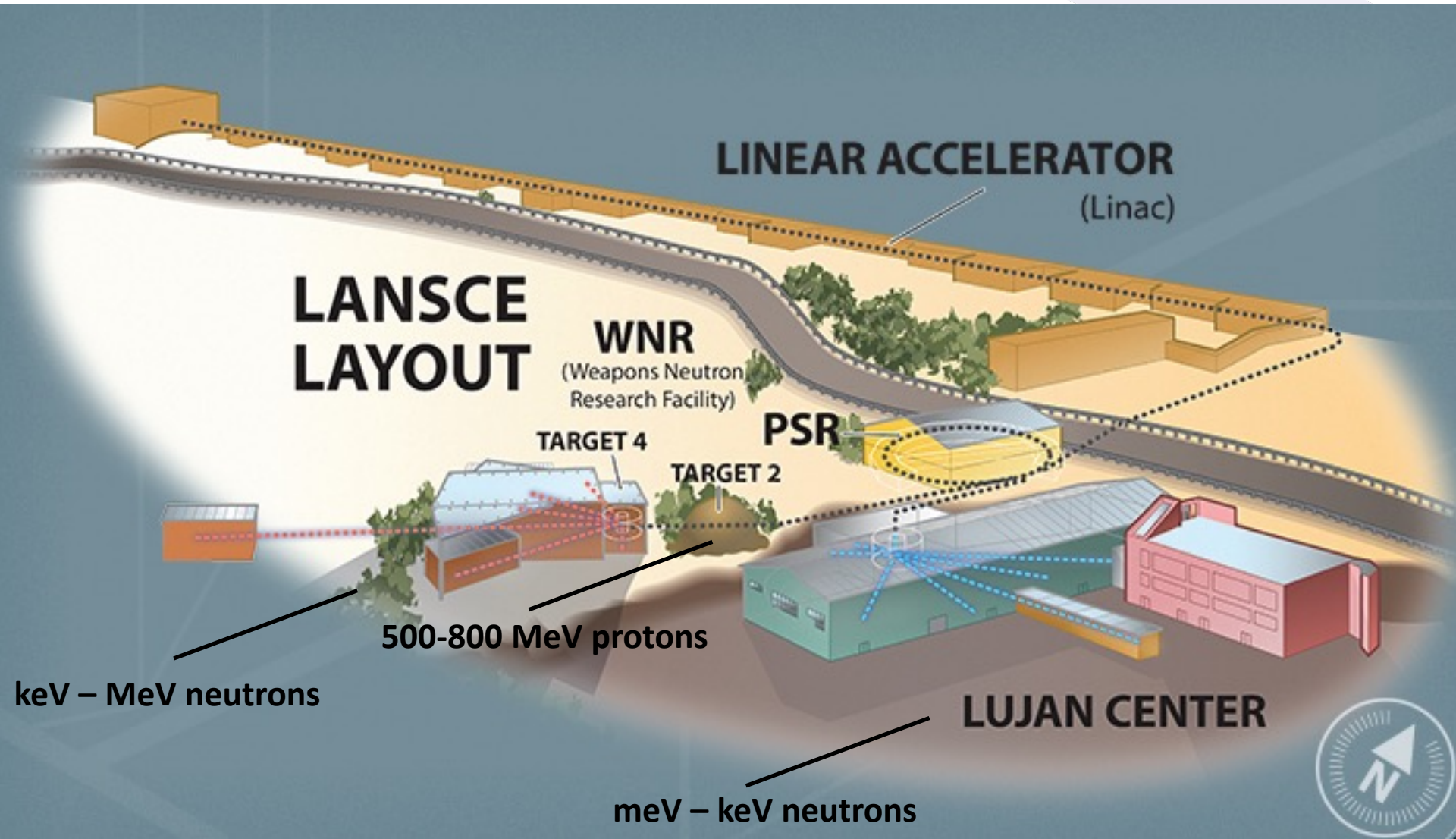


# Introduction: Summary

- **We performed capture and transmission measurements with:**
  - **the DANCE (Detector for Advanced Neutron Capture Experiments) instrument**
  - **Capture data from 8 eV – 1 keV**
  - **and DICER (Device for Indirect Capture Experiments on Radionuclides) instruments**
  - **Transmission data from 1meV – 1 keV**
- **Data analysis is complete**
- **R-Matrix analysis is complete**
- **Report with resonance parameters to be used in next evaluations:**

**LA-UR-23-32571**  
**Combined study of  $n+^{149}\text{Sm}$  with DANCE and DICER at LANSCE**  
**A. Stamatopoulos, P. Koehler, E. Leal-Cidoncha**
- **Phys. Rev. C manuscript is being reviewed by co-authors**

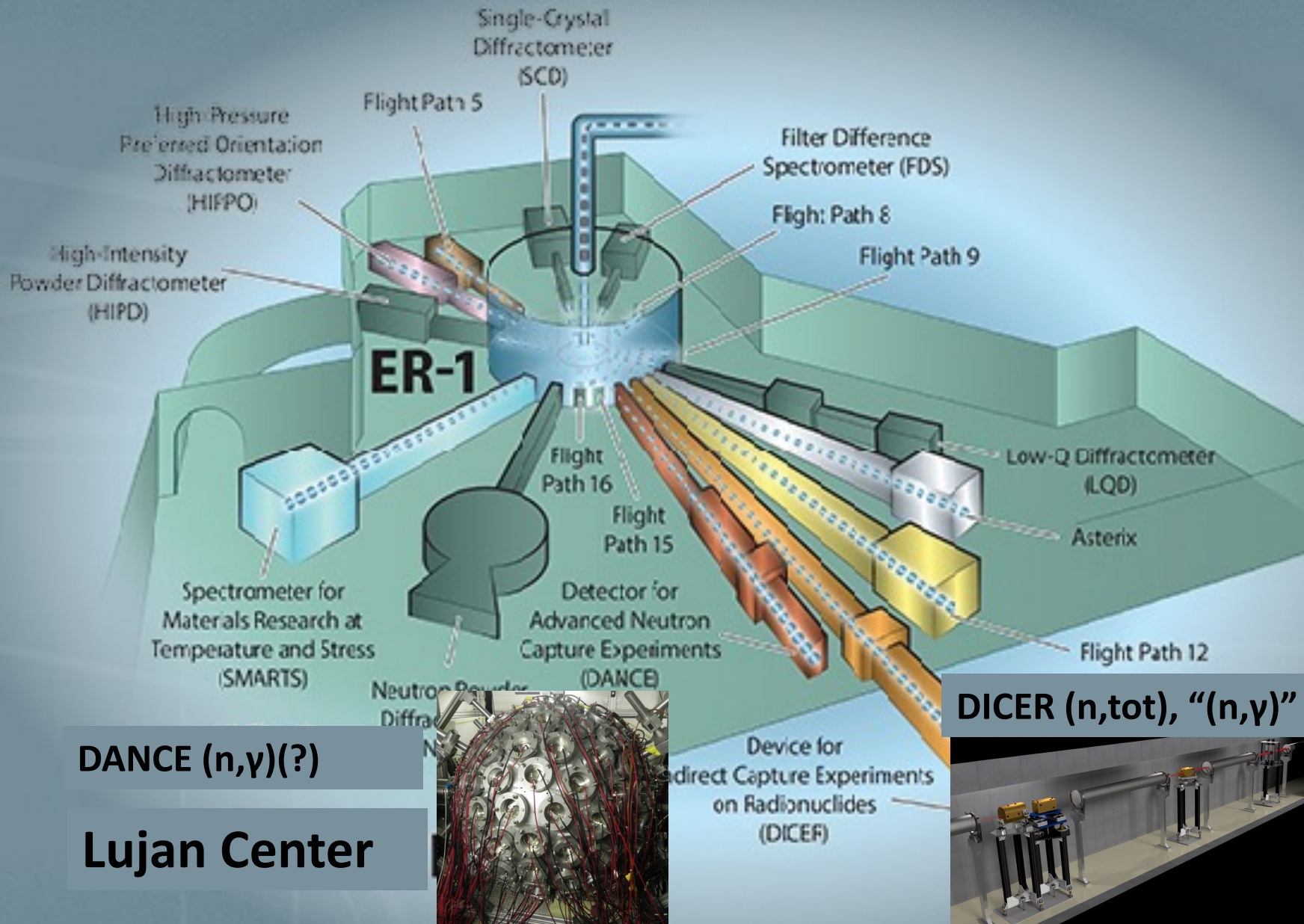
# The Los Alamos Neutron Science Center - LANSCE





# The Los Alamos Neutron Science Center – LANSCE

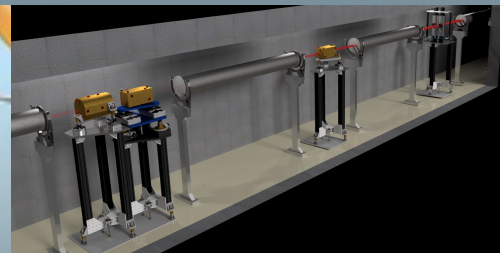
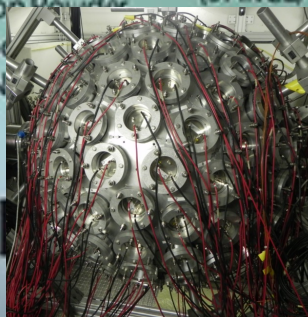
## Lujan Center – Low energy neutrons



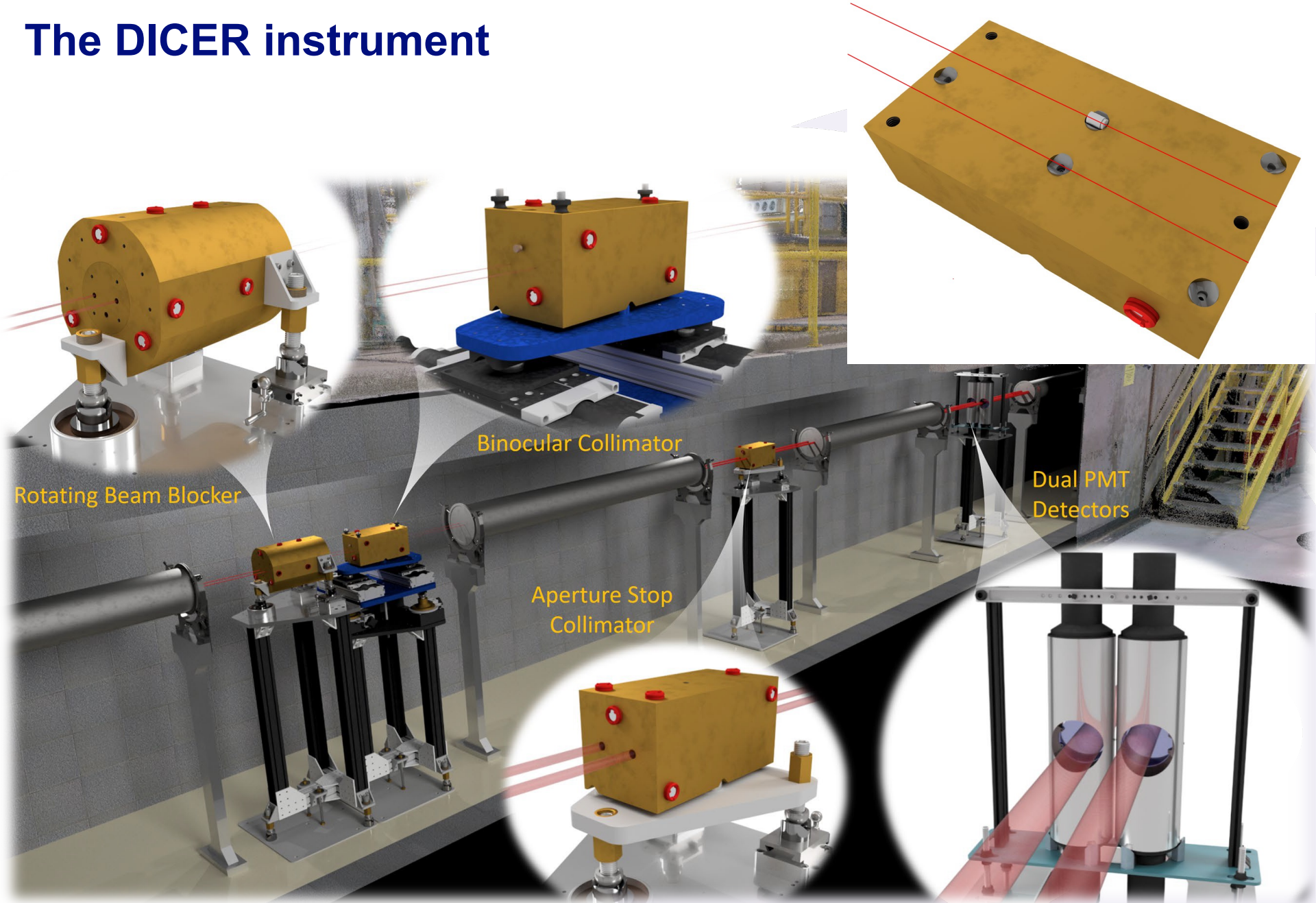
DANCE (n, $\gamma$ )(?)

Lujan Center

DICER (n,tot), “(n, $\gamma$ )”



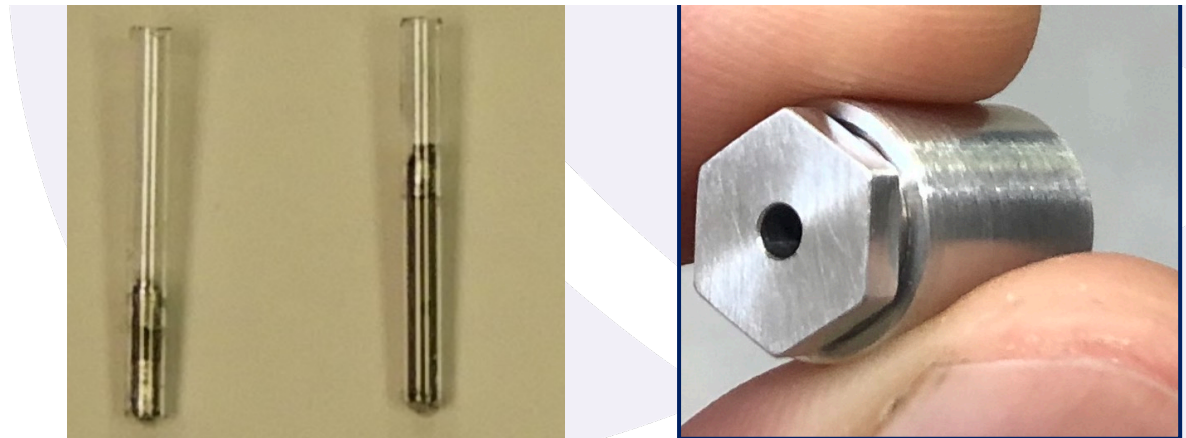
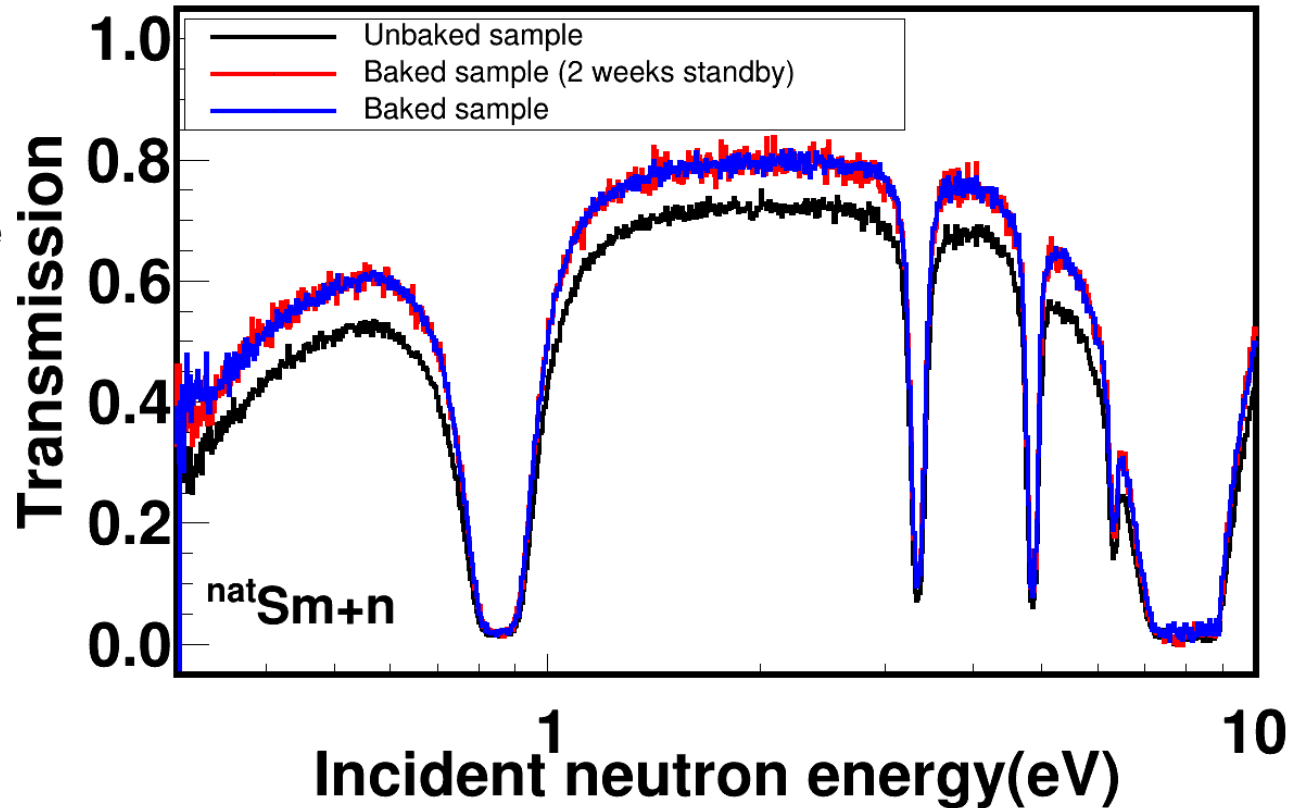
# The DICER instrument





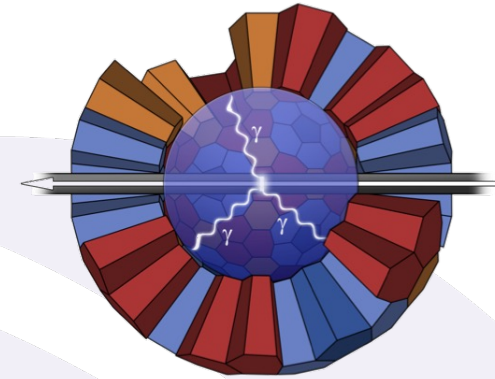
# Experiments @ DICER

- $^{nat}\text{Sm}$  experiments were performed prior, in order to:
  - Get experience with the target fabrication
  - Get experience with powdered samples at DICER
- ~5mg  $^{149}\text{Sm}$  thin sample
- ~12mg  $^{149}\text{Sm}$  thick sample
- 1 mm diameter
- 97.669% purity
- Powder stuffed in capillary tubes
- Capillary tubes inserted in Al canisters

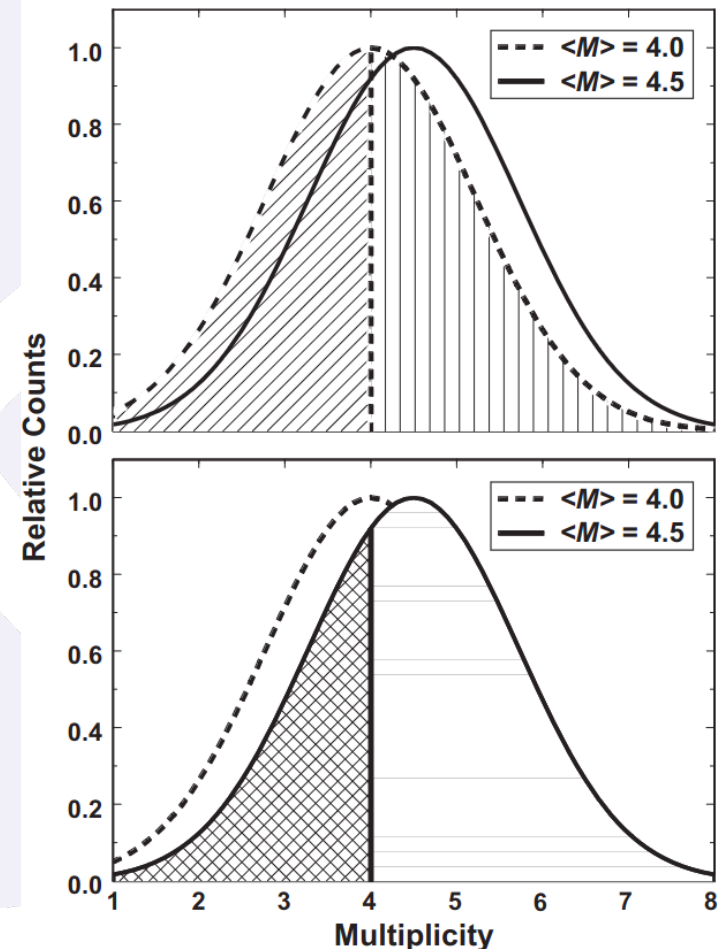
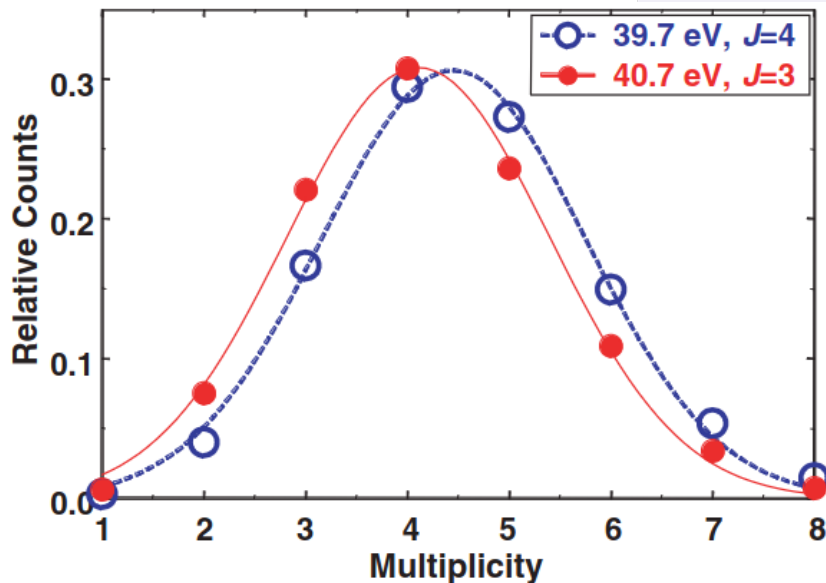


# Experiment @ DANCE

- DANCE to get the capture yields
- There metallic samples were used
  - 97.93% purity
  - 1,3 and 10 mg
  - 1cm in diameter
- DANCE also provides multiplicities
- Different multiplicity distributions for different spins
- DANCE is used as a spinometer



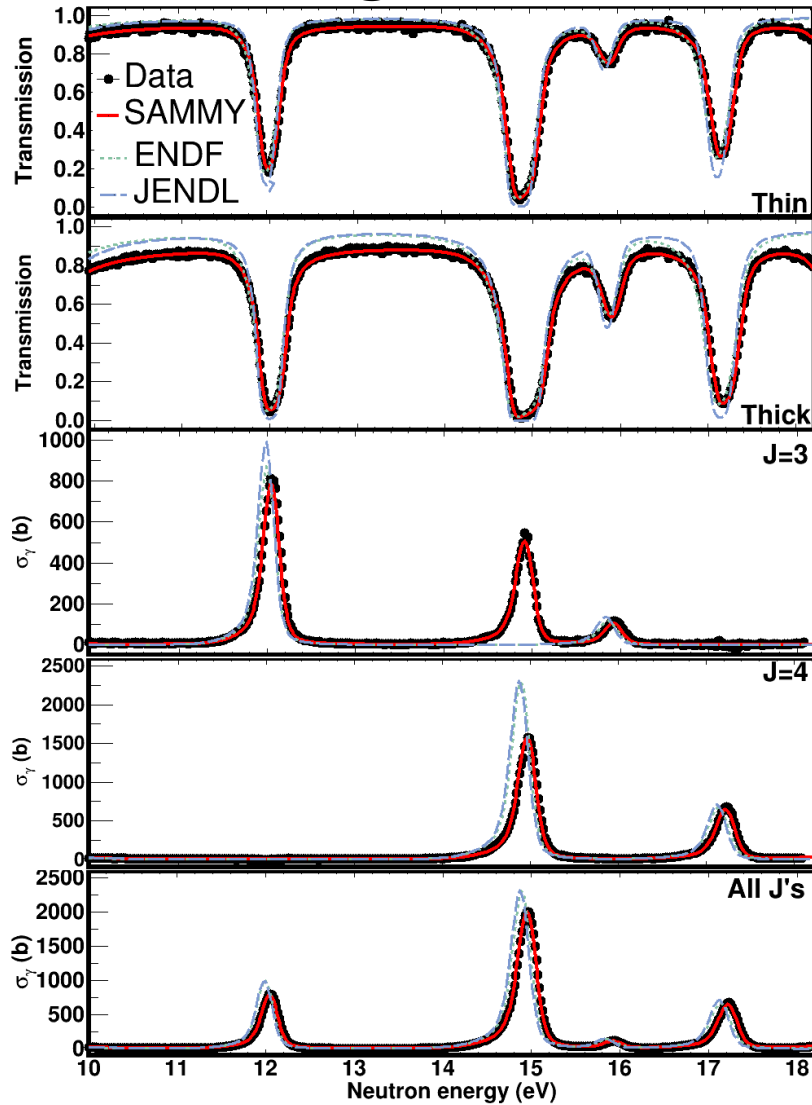
PHYSICAL REVIEW C 76, 025804 (2007)



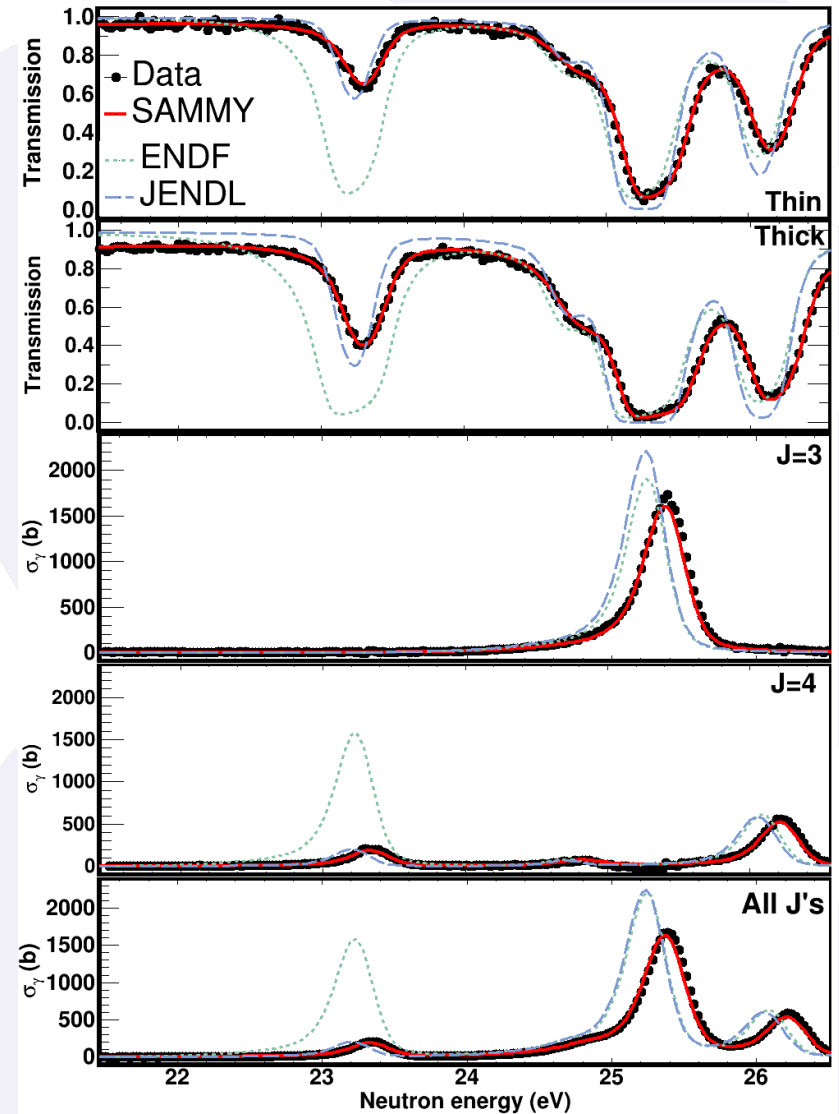
# R-Matrix analysis : Resonance parameters

- Fits in capture and transmission data using SAMMY

Resolved doublet @ 15 eV



Evaluated  $\Gamma_n$  is too large



# R-Matrix analysis : Resonance parameters

- 163 resonances were resolved, up to ~521 eV
- Uncertainties on  $\Gamma_\gamma$  : less than 13%, average uncertainty: ~3.5%
- Uncertainties on  $\Gamma_n$  : less than 18%, average uncertainty: ~3.8%

TABLE III: List of  $^{149}\text{Sm}$  resonance parameters obtained from the present work along with their uncertainties. In cases where the data were insensitive to the corresponding width, ENDF values were adopted. In those cases, the uncertainties are marked with a dash.

En (eV)	$\delta\text{En}$	$\Gamma_\gamma$ (meV)	$\delta\Gamma_\gamma$ (%)	$\delta\Gamma_\gamma$ (%)	$\Gamma_n$ (meV)	$\delta\Gamma_n$ (%)	$\delta\Gamma_n$ (%)	J
-123.7000	0.9277	60	-	-	2270	42.5	1.87	4
-88.4600	0.6912	64.9	-	-	6270	71.6	1.14	3
0.0970	0.0001	-65.62	-	-	0.545	0.000528	0.1	4
0.8703	0.0001	60.8	-	-	-0.749	0.000522	0.07	4
4.9450	0.0001	64	-	-	1.67	0.00169	0.1	4
6.4347	0.0001	66	-	-	0.847	0.0011	0.13	4
8.9112	0.0007	56.31	1.55	2.75	1.4	0.0103	0.74	3
8.9409	0.0002	77.86	0.27	0.34	7.19	0.0122	0.17	4
9.2017	0.0015	40.24	2.03	5.05	0.197	0.00422	2.14	3
12.0104	0.0001	67.58	0.32	0.47	1.74	0.00301	0.17	3
14.8669	0.001	57.12	1.78	3.12	1.45	0.0127	0.88	3
14.9166	0.0003	66.85	0.59	0.89	3.96	0.0127	0.32	4
15.8713	0.0006	63.85	1.45	2.27	0.323	0.00172	0.53	3
17.1631	0.0002	64.54	0.46	0.71	1.85	0.00387	0.21	4
23.2562	0.0005	97.55	1.33	1.36	0.908	0.0031	0.34	4
24.7428	0.0017	169.2	6.41	3.79	0.452	0.00671	1.48	4

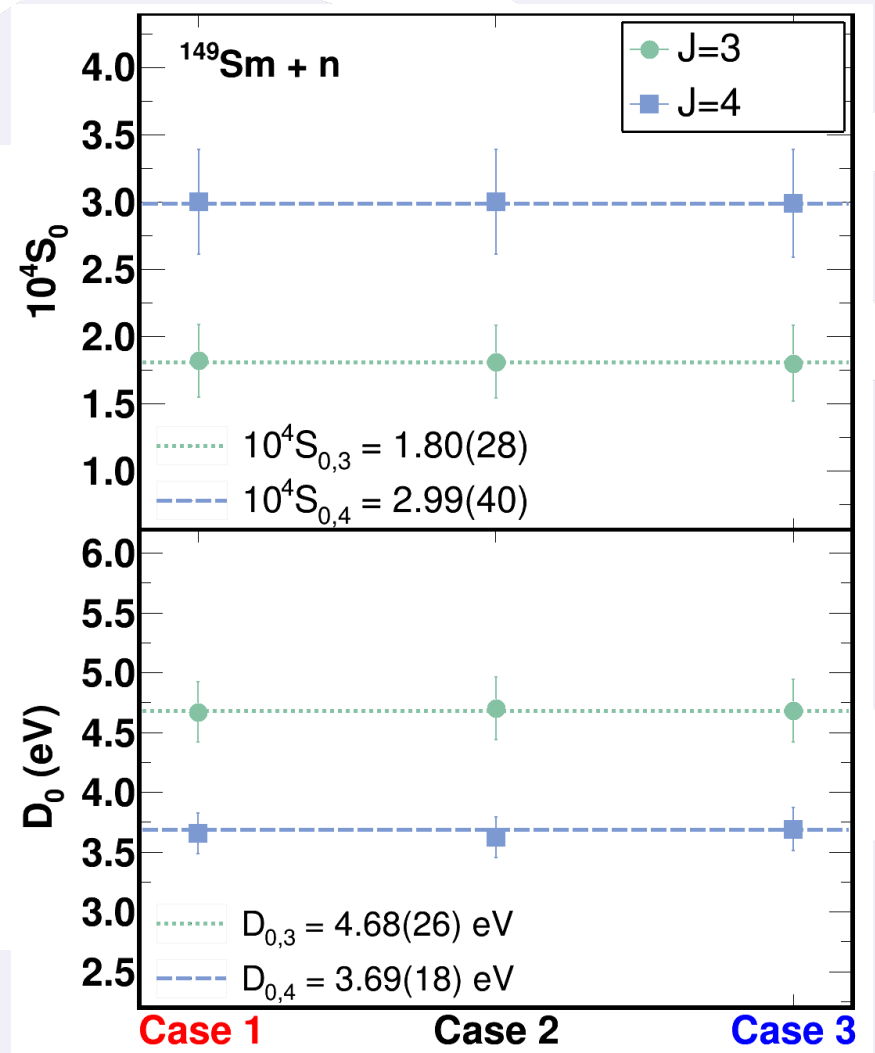
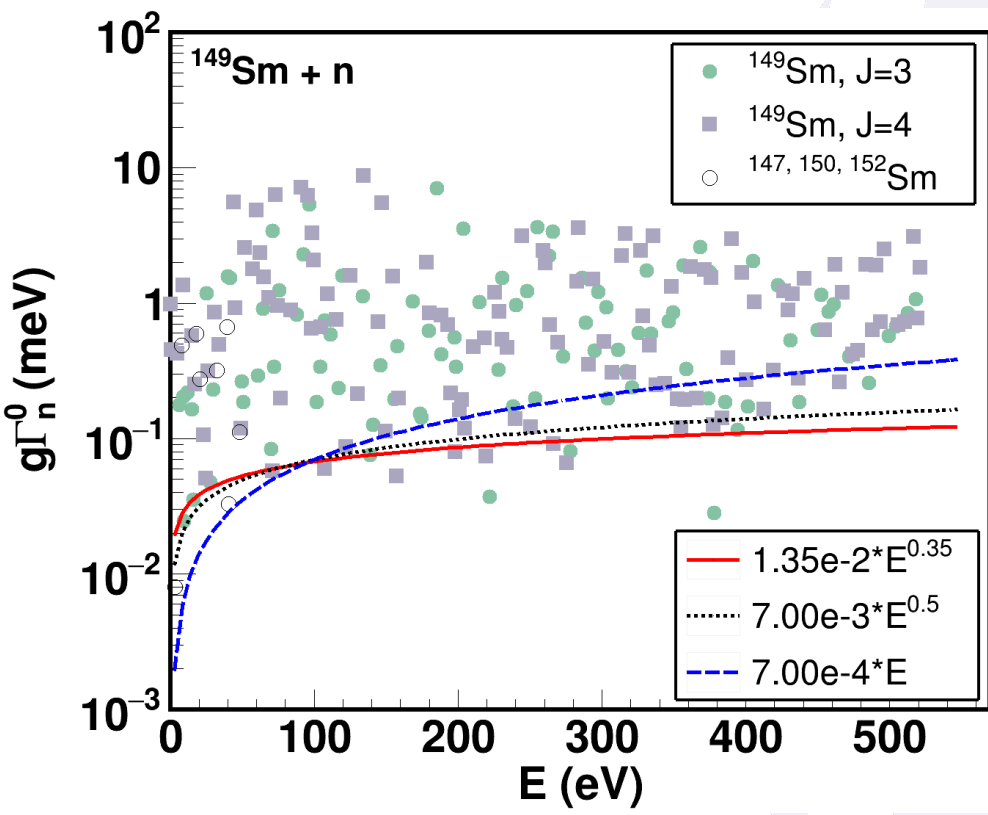
TABLE III – Continued from previous column

En (eV)	$\delta\text{En}$	$\Gamma_\gamma$ (meV)	$\delta\Gamma_\gamma$ (%)	$\delta\Gamma_\gamma$ (%)	$\Gamma_n$ (meV)	$\delta\Gamma_n$ (%)	$\delta\Gamma_n$ (%)	J
426.3241	0.0286	50	4.25	8.5	45	1.37	3.04	4
429.6465	0.0543	60	-	-	32.7	2.33	7.15	4
430.7652	0.1046	60.04	-	-	25.4	2.22	8.77	3
432.4598	0.0454	50.54	5.43	10.74	43.5	2.09	4.81	4
436.8267	0.1235	60	-	-	10.3	0.887	8.6	4
436.9302	0.1695	60.02	-	-	8.89	1	11.27	3
440.8384	0.0285	41.64	2.85	6.85	56.9	1.73	3.04	4
449.6931	0.0623	60.01	-	-	30.7	1.36	4.43	3
452.5806	0.0449	57.25	5.96	10.41	56.5	2.16	3.82	3
454.9622	0.0781	60	-	-	24	1.3	5.41	4
457.2479	0.0634	49.23	5.25	10.66	42.3	2.28	5.4	3
460.9260	0.0616	82.28	9.53	11.59	48.4	5.21	10.76	3
461.9848	0.0528	65.62	5.47	8.34	73.6	4.96	6.74	4
464.8767	0.2676	60	-	-	10.1	1.06	10.53	4
467.0235	0.0392	51.43	3.73	7.25	46.2	1.82	3.94	4
471.5969	0.0897	59.99	-	-	20	1.23	6.14	3
474.0793	0.1172	60	-	-	16.3	1.01	6.21	4
477.6819	0.0872	60	-	-	17.4	0.935	5.36	4
483.3276	0.0361	76.38	4.66	6.11	75.1	2.74	3.65	4
485.2824	0.2128	60	-	-	13	1.67	12.89	3
487.8185	0.0855	60	-	-	25	1.35	5.42	4
490.5794	0.0447	54.52	3.75	6.88	75.4	2.56	3.4	4
493.6053	0.1049	60	-	-	28.9	1.9	6.57	4
496.0529	0.043	62.74	3.25	5.19	-98.9	3.48	3.52	4
499.0333	0.081	53.66	9.58	17.85	29.3	1.83	6.24	3
504.3776	0.078	109.07	14.7	13.48	34.7	2.77	7.99	3
506.0744	0.0821	60	-	-	27.7	2.13	7.7	4
510.6419	0.0859	62.46	8.6	13.77	29.3	2.09	7.15	4
512.6020	0.0776	57.99	9.59	16.53	43.6	2.83	6.5	3
516.7416	0.0485	55.23	3.96	7.18	126	8.65	6.89	4
518.1875	0.1336	59.03	8.11	13.73	55.5	6.27	11.29	3
519.0864	0.2359	60	-	-	31.2	4.21	13.5	4
521.1491	0.0603	76.93	4.56	5.93	74.8	4.83	6.46	4



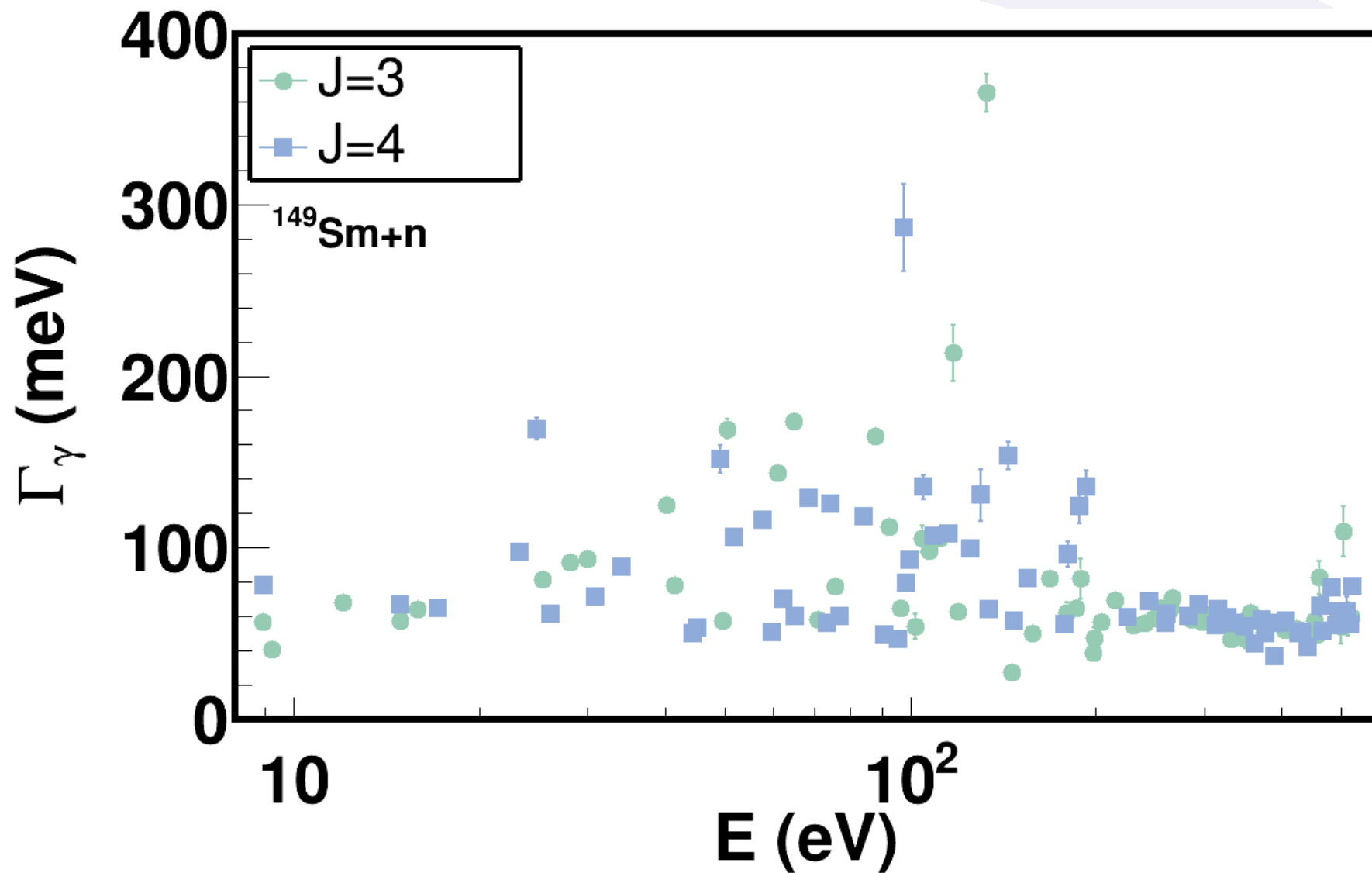
# Corrections

- Correction for missed resonances using Fuketa-Harvey method: Provides corrected number of resonances, strength functions ( $S_0$ ) and level spacings ( $D_0$ ).
- Similar corrections for various thresholds



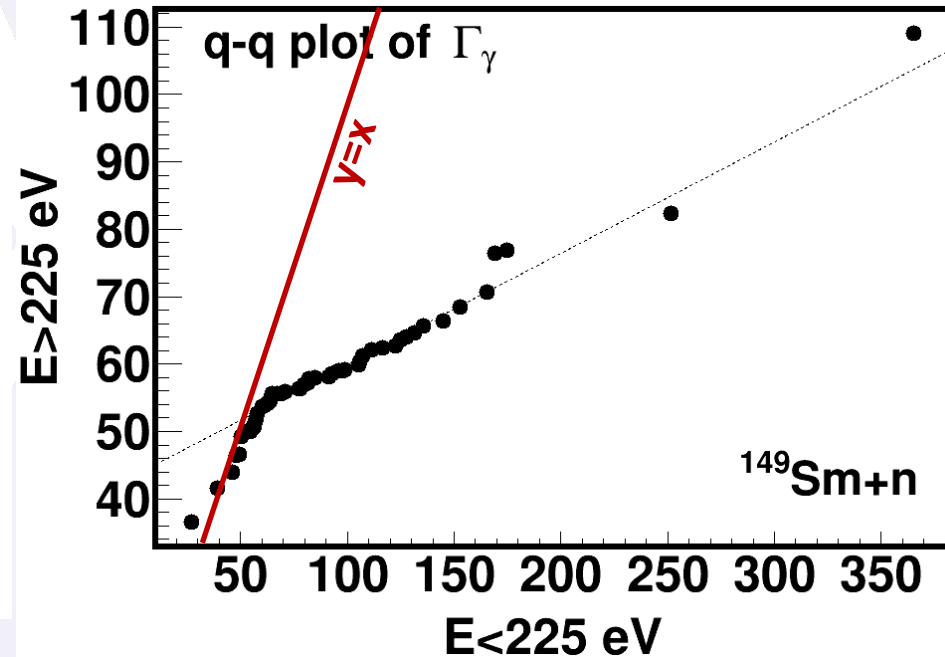
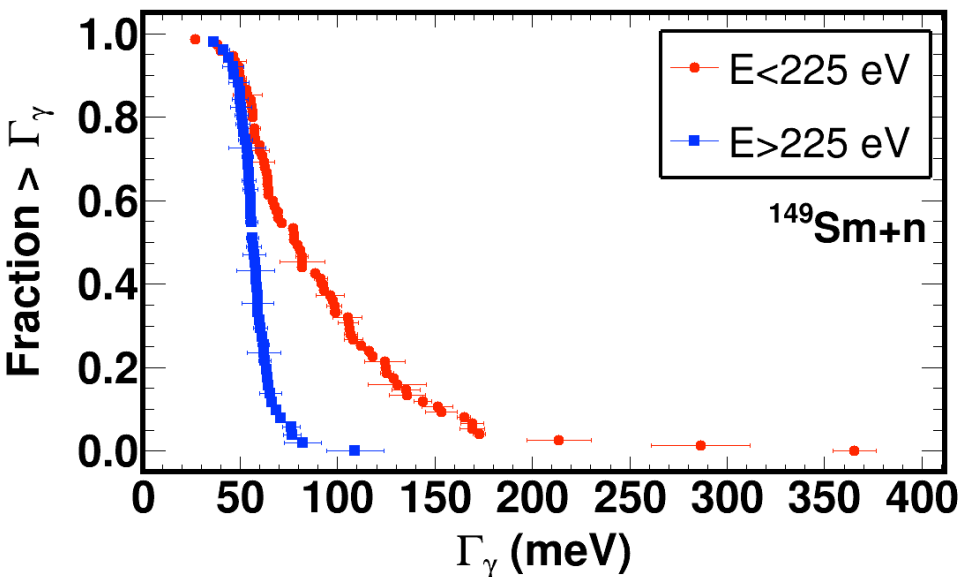
# Radiation widths

- Radiation widths seem to change distribution around 225 eV



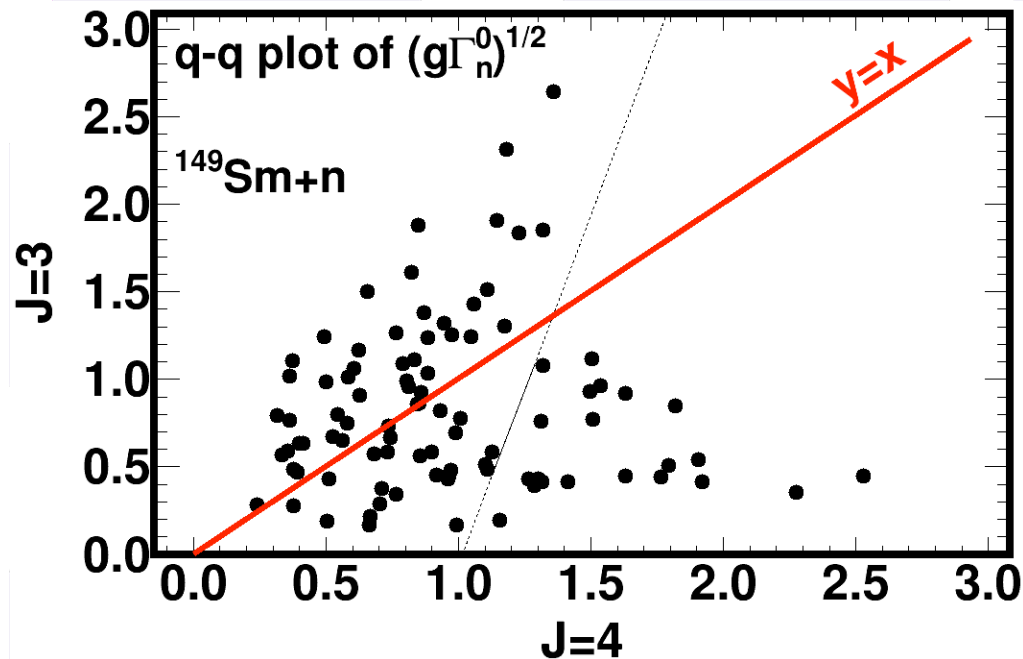
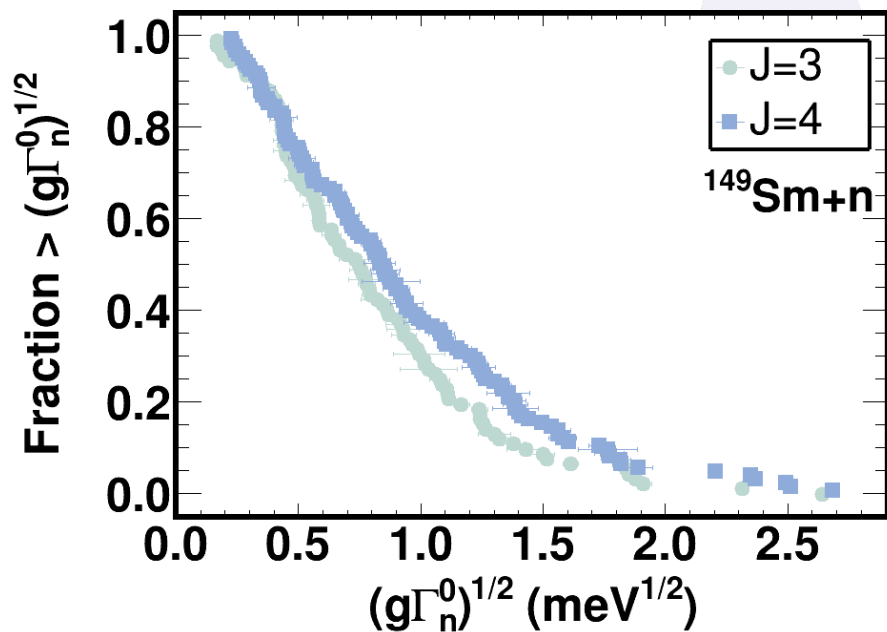
# Radiation widths

- Radiation widths seem to change distribution around 225 eV
- Kolmogorov-Smirnov (KS) test, which is sensitive to the tails, suggests they don't (KS statistics = 0.027, p-value = 0.0003)
- Anderson-Darling (AD) test, which is sensitive to deviations in both the center and the tails of the distributions, suggests that they are statistically different (p-value = 0.363)
- q-q plot suggest that overall, they come from the same distribution with different parameters.



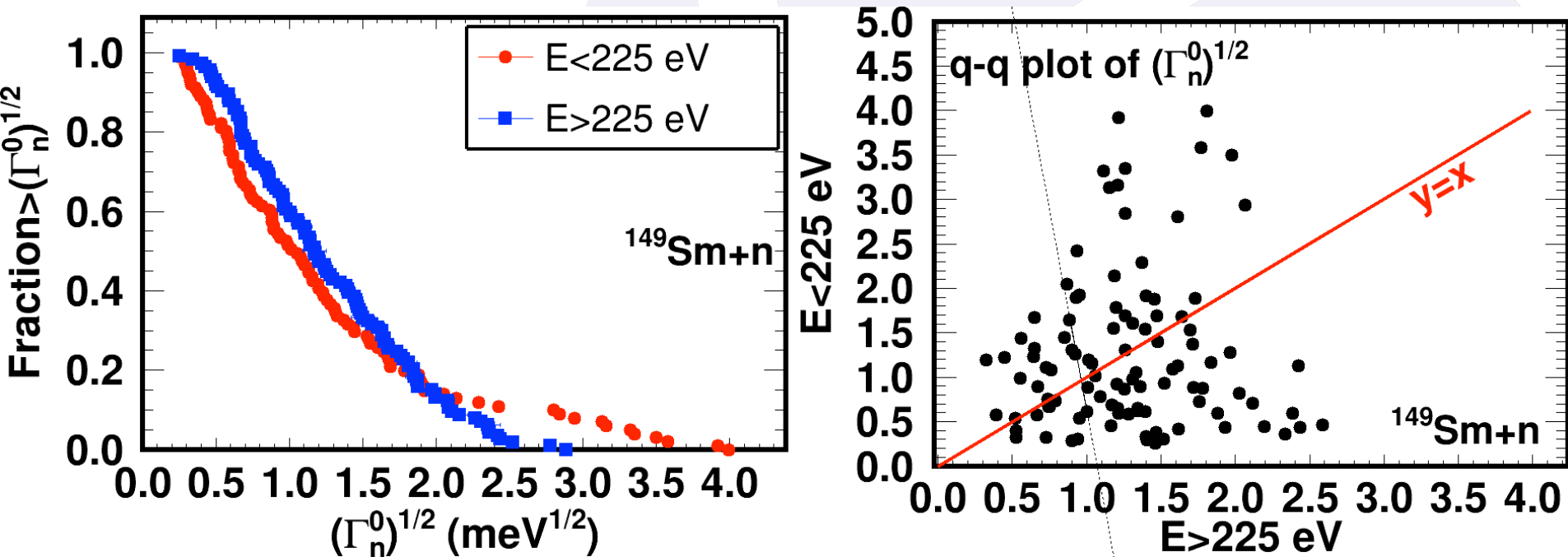
# Neutron widths

- Neutron width Cumulative Distribution Functions (CDFs) seem to be statistically similar, as expected for different angular momenta.
- KS test: p-value of 0.735, suggests that the two CDFs are statistically similar
- AD test: p-value of 0.361, suggests that the two CDFs are statistically similar
- q-q plot does not question the KS and AD tests.

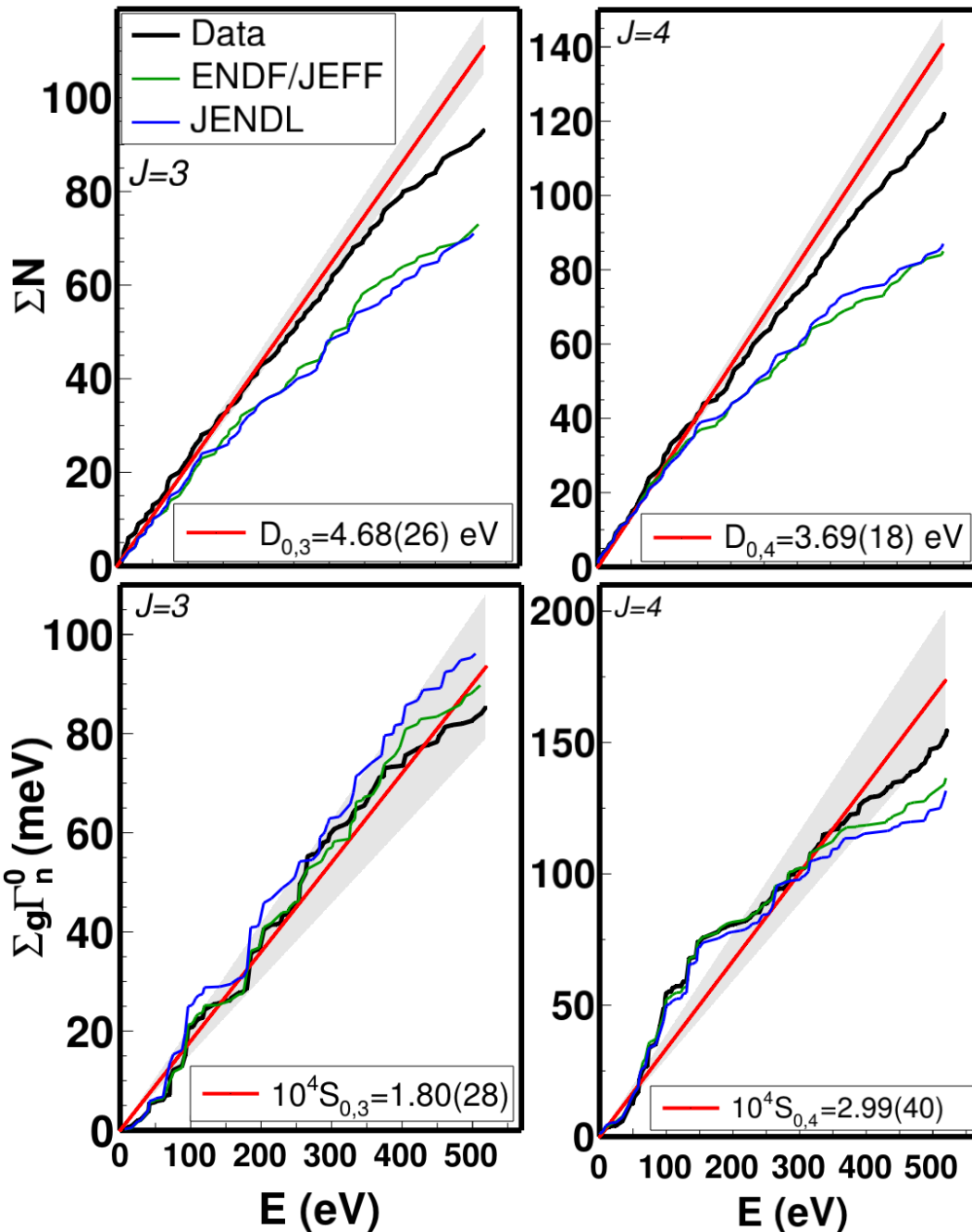


# Neutron widths

- Neutron width Cumulative Distribution Functions (CDFs) seem to be statistically similar across the whole energy range of the present work.
- KS test: p-value of 0.782, suggests that the two CDFs are statistically similar
- AD test: p-value of 0.360, suggests that the two CDFs are statistically similar
- q-q plot does not question the KS and AD tests.



# Level spacings, strength functions, comparison with evaluations



Our data indicate that:

- 38 spins are incorrectly assigned in the ENDF-VIII.0 and JEFF-3.3 evaluations
- 41 spins are incorrectly assigned in the JENDL-5 evaluation
- 58 new resonances were resolved
  - We resolved 215 resonances
  - Evaluations include 157 resonances
- Slight differences in the resonance energies
- Differences in resonance parameters up to 400%



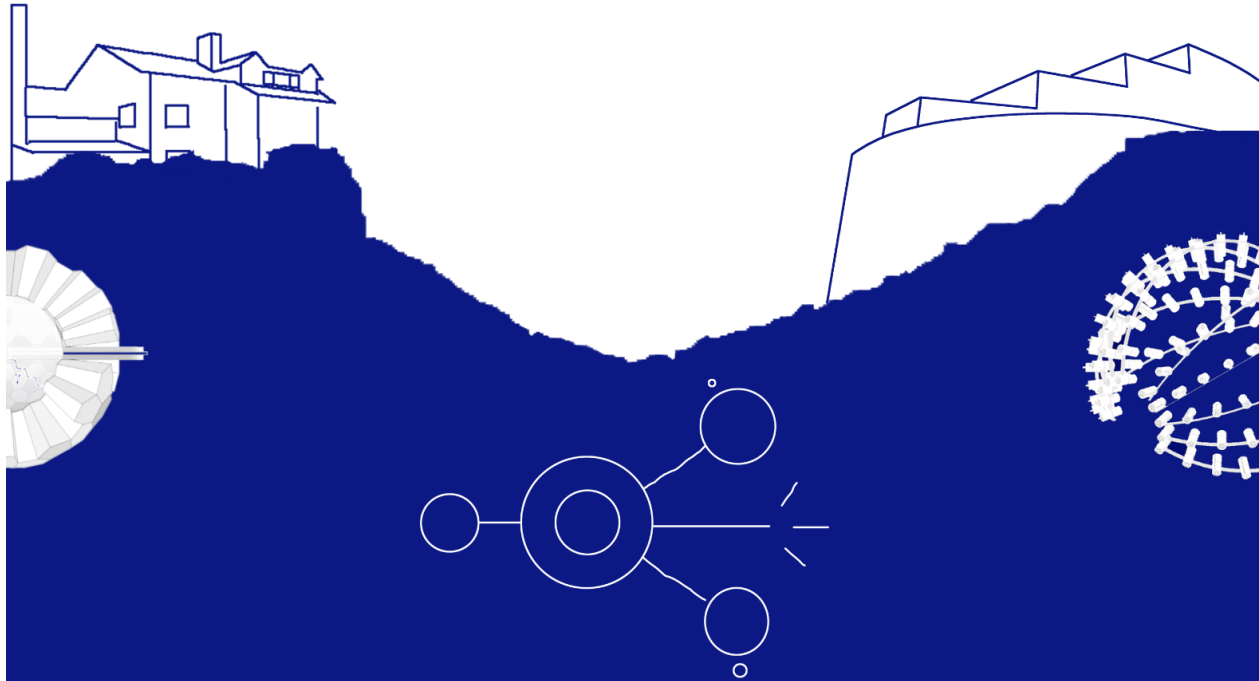
*Thank you for  
your  
attention!*





# FIESTA 2024

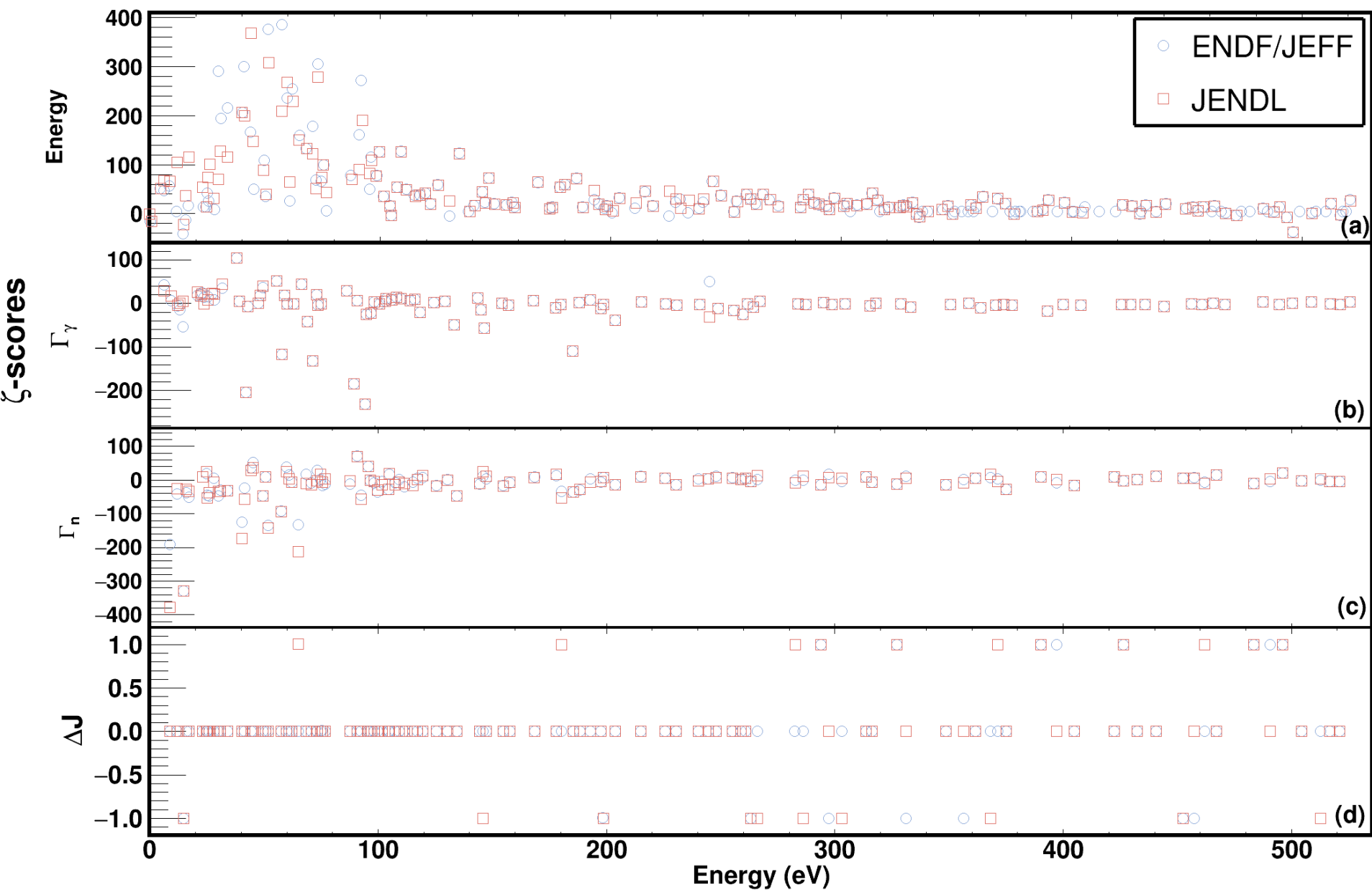
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NOVEMBER 18 - 22, 2024

# $\zeta$ -scores



# Resonance energies

